PURIFICATION OF SORBITOL USING REVERSE OSMOSIS MEMBRANE: EFFECT OF CROSS FLOW VELOCITY AND TRANSMEMBRANE PRESSURE

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ABSTRACT

Sorbitol, a sugar alcohol that has formula of $C_6H_{14}O_6$ also known as D-Glucitol. It can be obtained from the reduction of glucose, by changing the aldehyde group to hydroxyl group. It is very slow to metabolize in body, which lessen the chance of increasing the level of insulin, thus makes sorbitol is a good sweetener for diabetics. Since the use of sorbitol in the food industry more widely, sorbitol purity is a key factor before it is used as an additive in food. One of the method to purify sorbitol is application of membrane technology. However the membrane application is limited due tochallenges such as decay in permeate flux and increases the complexity of membrane operations. Thus, this research was conducted to study the effect of cross flow velocity (CFV) and transmembrane pressure (TMP) on the flux in purification of sorbitol using the reverse osmosis membrane. The flux was determined from the calculated of permeate flow rate divide by the area of spiral wound membrane. In order to study the optimize condition for the process, the value of TMP and CFV was varied to obtained the flux value. While varying the CFV value, the TMP value was constant and when the TMP was varied, the CFV was constant. This study was conducted for 60 minutes, and every 10 minutes the permeate flow rate was collected to get the flux value. The solution was prepared with constant concentration of 10g/L in a 100 L solution in tank. The determination of sorbitol was analyze by refractometer. Based on the result obtained, increasing in CFV and TMP give the highest flux value.

ABSTRAK

Sorbitol, sejenis gula alkohol yang mempunyai formula $C_6H_{14}O_6$ juga dikenali sebagai D- Glucitol Ia boleh diperolehi daripada pengurangan glukosa, dengan menukar kumpulan aldehid kepada kumpulan hidroksil. Ia sangat lambat untuk dimetabolismekan dalam badan , dimana dapat mengurangkan peluang peningkatan tahap insulin maka menjadikan ianya sesuai sebagai pemanis bagi pesakit kencing manis. Oleh kerana penggunaan sorbitol dalam industri makanan sangat meluas, ketulenan sorbitol adalah faktor penting sebelum ia digunakan sebagai bahan tambahan dalam makanan. Salah satu kaedah untuk menulenkan sorbitol adalah penggunaan teknologi membran. Walau bagaimanapun penggunaan membran adalah terhad disebabkan cabaran seperti penurunan fluks dan meningkatkan kerumitan operasi membran. Oleh itu, kajian ini telah dijalankan untuk mengkaji kesan halaju aliran silang (CFV) dan tekanan transmembran (TMP) pada fluks dalam penulenan sorbitol menggunakan membran osmosis berbalik. Fluks ditentukan daripada kadar aliran isipadu dibahagi dengan luas membran. Dalam usaha untuk mengkaji keadaan yang paling optimum untuk proses, nilai halaju aliran silang dan tekanan transmembran telah diubah untuk memperolehi nilai fluks. Apabila nilai nilai halaju aliran silang diubah, maka nilai tekanan transmembran adalah tetap dan sebaliknya. Kajian ini dijalankan selama 60 minit, dan setiap 10 minit kadar aliran isipadu dikumpulkan untuk mendapatkan nilai fluks. Larutan sorbitol disediakan dengan kepekatan tetap pada 10g/L di dalam larutan tangki 100 L. Sorbitol ditentukan dengan menganalisis menggunakan refraktometer. Hasil yang diperolehi menunjukkan peningkatkan halaju aliran silang (CFV) dan tekanan transmembrane (TMP) memberi memberikan nilai fluks yang maksimum.

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J	Flux
LMH	Flux through the membrane
t	Time
Q	Volume flow rate

LIST OF ABBREVIATIONS

CCD	Central Composite Design
CFV	Cross flow velocity
FTIR	Fourier transform infrared spectroscopy
ICP-MS	Inductively coupled plasma – mass spectrophotometer
MW	Molecular weight
MWCO	Molecular weight cut off
OFAT	One factor at a time
RO	Reverse osmosis
RSM	Response surface methodology
SEM	Electric resistance tomography
TMP	Transmembrane pressure

1 INTRODUCTION

1.1 Background of research

Polyols was commonly used for personal care industry, both the cosmetics and toiletries sectors and began to play an important role in a market characterized by growing interest in alternatives to animal-derived ingredients. Therefore, polyols were incorporated as excipients in the manufacture of the essential ranges of personal care products like toothpaste, creams and lotions, make-up, perfumes or deodorants.

Sugar alcohols were a class of polyols in which sugar's carbonyl, ketone or aldehyde is reduced to the corresponding primary or secondary hydroxyl group. Sorbitol is a sugar alcohol that has the molecular weight of 182.17 g/mole and melting point of 95^{o}C while the boiling point is 296^{o}C. The IUPAC name for sorbitol is (2S,3R,4R,5R)-hexane-1,2,3,4,5,6-hexol. Sorbitol is about 60% as sweet as sucrose with 1/3 fewer calories. It has been safely used in processed foods for almost half a century, also used in other products such as pharmaceuticals and cosmetics. (Baines *et al*., 1975), U.S. Patent 3927201, states that the refractive index of sorbitol as a 70% solution in water is 1.45.

Developed in the 1950s, sorbitol was the most consumed sugar alcohol. In all applications, demand for sorbitol was largely a function of its unique combination of functional properties as a humectant, sweetener, bulking agent, stabilizer, softener, emulsifier, and its surface-active properties. Applications in personal care products (mainly toothpaste), food and confections and in the manufacture of vitamin C accounted for 78% of world consumption in 2007 and continue to account for over 75% of world demand in the near future. (Bizzari *et.al*)

Although sorbitol were less effective than xylitol in controlling the caries, but the lower cost of sorbitol makes it to be more demanding to be used as the sugar substitute in the food manufacturing. It is also be consumed by people in relatively large amount without side-effects. However, they can act as a laxative. It does not promote caries because it metabolized either slowly or not at all in dental plaque. For people with diabetics, there was some restriction for them to consume the glucose continuously. But, they was advised to take the artificial sweetener such as sorbitol, that has a fewer calories than glucose. It has been recommended used in dietetic food products which it lends palatability and bulk. It was believed converted to glycogen to be liberated as glucose without producing hyperglycemia.

In this study, a reverse osmosis membrane was used in performing the purification process that increased the purity of sorbitol. However, during the process problems such as flux declination during the separation process, that can be reduced by applying a high transmembrane pressure and high cross flow velocity, thus will improve membrane flux and reduce the fouling of the membrane. Reverse Osmosis has many advantages over the conventional water and wastewater treatment operations and processes. It is able in removing many dissolved substances efficiently, yet produce good quality finished water. It does not require any addition of chemicals into the water for separation. The separation of the dissolved substances from the influent is achieved physically or physico-chemically. It is essentially a molecular squeezing process, using a semi-permeable membrane which causes water molecules to separate from the contaminants then the separated water molecules pass through to the inside of the membrane to a holding reservoir. Recently, reverse osmosis has been used in treating boiler feed water, in addition to industrial and process wastewaters. Boilers are found throughout the chemical processing industry and the primary method to treat boiler wastewater is ion-exchange. However, reverse osmosis has been demonstrated to be more cost effective than this demineralization process.

The International Union of Pure and Applied Chemistry (IUPAC) define reverse osmosis as a “pressure-driven process in which applied transmembrane pressure causes selective movement of solvent against its osmotic pressure difference” (IUPAC 1996). Reverse osmosis (also called hyperfiltration, is capable of the highest filtration level possible, including separating dissolved salts and removing bacteria, pathogens and organics from water. The applications of reverse osmosis include but are not limited to separation and concentration of solutes in many fields, such as chemical and biomedical industry, food and beverage processing, and water and wastewater treatment.

Wide application of reverse osmosis such as for seawater desalination, groundwater treatment, and for tertiary treatment to reclaim the secondary effluent for advance reuses purposes. In addition to removing total dissolved solid, reverse osmosis is very effective in reducing other minerals, ammonia, and total organic carbon (TOC). The membranes remove 90 percent of total dissolved solid. It is useful for separating thermally and chemically unstable products.

1.2 Motivation

Nowadays, the number of patients with diabetics had achieved a very alarming number. One of the factors of diabetics is the diet that is taken by the people worlds wide besides obesity and sedentary lifestyles (Vischer et al, 2009). Unstable diet with high content of sugars can causes diabetics. Surprisingly, Malaysia has one of the world's greatest numbers of diabetic cases among its population with 2.6 million registered patients (Adie, 2012). Untreated diabetics may cause chronic renal failure (Mauro *et al*, 2001). Sugar substitute products regulate sugar intake by consumers, which helps promote healthy weight maintenance and improve blood glucose control. Hence, play an important role in the health and well-being of an individual. The benefits of consuming these substitutes sugar are highly valuable for all people that also have skin smoothing properties. (Chen, 1985)

Interest now arises because of their multiple potential health benefits. They are non-cariogenic (sugar-free tooth-friendly), low-glycaemic (potentially helpful in diabetes and cardiovascular disease), low-energy and low-insulinaemic (potentially helpful in obesity), low-digestible (potentially helpful in the colon), osmotic (colon-hydrating, laxative and purifying) carbohydrates. Glycaemic Index values on replacing sucrose were independent of both intake (up to 50 g) and the state of carbohydrate metabolism.

Although it is not an essential nutrient, they contribute to clinically recognized maintenance of a healthy colonic environment and function. A role for polyols to hydrate the colonic contents and aid laxation is now recognized by physicians and favors saccharolytic anaerobes and aciduric organisms in the colon, purifying the colon of endotoxic, putrefying and pathological organisms, which has clinical relevance. Polyols also contribute towards short-chain organic acid formation for a healthy colonic epithelium.

1.3 Problem statement

Lacking of previous research that in purification of sorbitol using the membrane separation techniques. The problem of this research is to find the most appropriate condition that can enhance the purification of sorbitol using the low pressure reverse osmosis membrane. The purification of sorbitol is important in order to remove the impurities to produce pure product. The impurities will then reduce the quality of sorbitol hence the economic value will be low.

Although application of membrane purification is the most effective process at present, the challenges for membrane purification of sorbitol because of problem faced is decay in permeate flux, which cause by fouling. In order to reduce the fouling by varying the transmembrane pressure and cross flow velocity to the optimum condition thus enhances the membrane flux.

Thus, this research proposed studying the purification process of sorbitol using membrane technology and determining the factors that affect the permeate flux. The suitable parameters that will be determined include cross flow velocity (CFV) and transmembrane pressure (TMP).

1.4 Objectives

The main objective of this research is to purify Sorbitol by using Low Pressure Reverse Osmosis Membrane System.

This research also has a few specific objectives that are:

i. To determine the effect of cross flow velocity and transmembrane pressure on flux during sorbitol filtration.
ii. To determine the optimum condition of sorbitol flux using RSM.

1.5 Scope of this research

The scopes of study are:

1) Purification using GE Membrane was focused in this study.
2) Transmembrane pressure and cross flow velocity was adjusted to determine the membrane flux.
3) The volume of permeate and retentate was collected every 10 minutes.
4) The sample was analyzed by Fourier Transform Infra-Red (FTIR), refractometer, and ICPMS.
5) The optimization condition of operating parameters, including cross flow velocity (CFV) and transmembrane pressure (TMP) has been done by the Response Surface Methodology (RSM)

1.6 Thesis outline

This report contains five chapters that consist of first chapter that includes the background of research, problem statement, objectives of the research, scopes of study, and thesis outline. Second chapter is the literature review on sorbitol, purification, membrane, CFV, TMP, membrane cleaning and analysis performed. Methodology was discussed in chapter 3 which comprises of materials and experiment procedures. The discussions of the findings are delivered in Chapter 4 that discusses about effect of cross flow velocity (CFV) and transmembrane pressure (TMP) towards permeate flux. While Chapter 5 presents the conclusion and recommendation of this study.

2 LITERATURE REVIEW

2.1 Overview

Table 2-1: Properties of sorbitol and xylitol

Sorbitol	Xylitol
Synonym: D-Glucitol, D-Sorbitol	Synonym: D-Xylitol, D-xylo-Pentane-1,2,3,4,5-pentol
Chemical formula: $C_6H_{14}O_6$	Chemical formula: $C_5H_{12}O_5$
Molecular weight : 182.17 g/mole	Molecular weight : 152.15 g/mole
Boiling Point: 295 ^oC (563.00ƒF)	Boiling Point: : 216°C (420.8°F)
Melting Point: 75 ^0C (167.00ƒF)	Melting Point: 94°C (201.2°F)
Critical Temperature: Not available.	Critical Temperature: Not available
Specific Gravity: 1.489 (Water = 1)	Specific Gravity: 1.52(Water = 1)
Solubility in water: 55% @ 25^oC	Solubility in water: Easily soluble in cold water. Soluble in methanol.
Color: colorless or white	Color: White
Odor: odorless	Odor: Odorless

Based on Table 2.1, it shows the comparison properties of sorbitol and xylitol, both is a sugar alcohol that they might shows or exhibit the same characteristics. However the chemical formula was different where sorbitol, has six number of carbon while xylitol has only five number of carbon. The properties of sorbitol (IUPAC) are fairly similar to those of its stereoisomer, mannitol. However the solubility of sorbitol in water is significantly higher than mannitol. At 25^oC the solubility of sorbitol in water is only approximately 55% while for xylitol easily soluble in cold. Sorbitol is sparingly soluble in organic solvents like ethanol, and glycerol and practically insoluble in ether, ketone and hydrocarbons. The relatives sweetness to sucrose are varies among different sugar alcohols. The relative sweetness of xylitol is 100%, mannitol is 40-50% and sorbitol, 60%. (Schiweck *et al*. 1994)

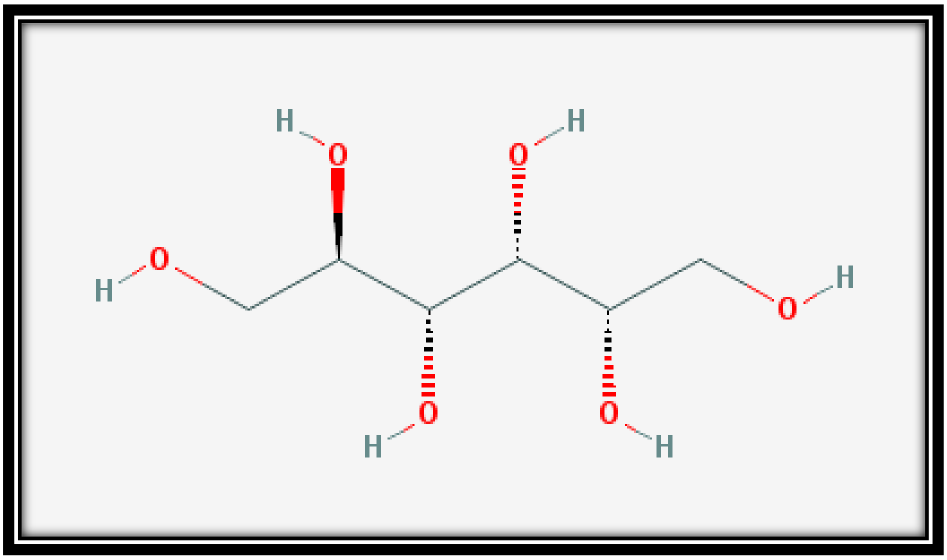

Figure 2-1: Sorbitol structure formula

Sorbitol sweetener is a sugar alcohol that's derived from glucose by modifying one of the chemical groups so that it's metabolized more slowly by the body. This reduces the insulin surge that normally occurs when sugar is ingested. Sorbitol can be found naturally in some fruits or can be obtained from glucose catalytic hydrogenation and at only 2.6 calories per serving it offers significant calorie advantages over table sugar (Cazetta *et al*, 2005). This is because fermentation process involves biological systems which are less controllable and more complex than straightforward chemical reactions, the variability in products derived by fermentation is often greater than in products derived by chemical synthesis. Thus, the impurity profile of a fermentation product may be more complex and less predictable than that of a synthetic product. (Canary, 2010) Usually the production of sorbitol is accomplished in a hydrogenation process however, reactions like hydrolysis and hydrogenation may be involved in the same reaction system due to the rapid development of research.

Besides of the application in food industry, in pharmaceutical and medicine it can be used to decrease cellular edema and medicine it can be used to determine increase of urinary output. The chemical structure of sugar alcohol allows them to be absorbed more slowly in the body than regular sugars. Therefore, they have smaller impact on blood insulin level. Individuals, who should not eat sugar such as diabetic patient, now can consume the artificial sweetness, due to the sweet taste of sugar alcohols combined with the independence of insulin when metabolized by body. (Weymarn, 2002)

The reduced caloric values are due to the facts that sugar alcohol is only partially absorbed in the upper intestine. Thus, a large part of the ingested sugar alcohols reached the large intestine, where bacteria degrade it. (Schiweck *et al*., 1994) sugar alcohol is commonly used for production of reduced-calorie products, because of the reduced caloric value compared to most sugar. However, incomplete absorption can results to diarrhea, a gastrointestinal effects, hence the daily intake of polyols should not exceed 20g (Anon, 2001)

2.2 Purification

Purification is a process that removes the remaining impurities which typically are similar to those of target product. (R. Ghosh, 2006). According to Shawn(1999), the first chromatographic techniques that is paper and thin-layer chromatography were used to separate sugars, but the separations were limited with respect to number of recognized analyses, presented poor resolution and not always quantitative, while the efficiently methods for purify specific carbohydrate to high degree of purity using the semipermeable membrane reverse osmosis.

For the identification of all, polyols still did not have single method that is universally applicable. In previous preliminary analyses of plant material, paper chromatography is very frequently used where the application of this method requires little specialized equipment and because it has proved most useful for examining material. Purification in chemical industries is important in pharmaceutical industries such that positive results of quality control and cost of purification step or steps are that won’t be available without optimized process conditions and choosing the best purification method.(Salehparhizkar, 2009).Table 2-2 summarize the different types of separation process by using different separation methods.

Table 2-2: Different types of separation process

Type of system	Characteristics	Process	Result	References
Ultrafiltration (in organic membrane)	Pore size: 20 100nm 0.8 m long Filtration area - $0.2m^2$	Purification of different liquid materials from food industry	-Amaranth starch solution was concentrated 5 times while eg blend approximately 2-times in one step ultrafiltration process.	Hinkova *et al*. (2005).
Ion exchange chromatography (HPLC)	Column matrix	Purification of monosaccharide	-Bulk of contaminants was removed. - 8 µg of glucose contamination per milligram of ultrafiltered enzyme remained.	Hodgins. G. W.L. *et al*
Nanofiltration	Polysufone membrane	Purification of xylose from hemicellulose hydrolyzate feeds	Purified xylose	Sjoman *et al*. (2006)
Tangential flow microfiltration and ultrafiltration	Polyvinylidene fluoride (PVDF) membrane	Separation of hyaluronic acid from the fermentation broth of *Steptococus Zooepidemicus*	Hyaluronic acid was separate from fermentation broth	Zhou *et al*. (2006)

2.3 Reverse osmosis membrane

The use of reverse osmosis (RO) membrane to remove salts and impurities from water has been a recognized technology to improve water quality. RO was being used in producing variety of high purity needs including industrial boiler feed, pharmaceutical waters, electronic industry supply and other process industries. It is proved to be used in water consolidation with microfiltration (MF), ultrafiltration (UF) evaporation or other water processes. The use of RO in wastewater is valuable application because permeate water can be reused and waste water stream becomes a resources in the stream. The benefits include reduced discharge, reduced purchases and conservation of water resources. (Zibrida *et al*., 2000).

Composition of the feed water largely controlled the performance of RO system where the quality of the feed water will determine the amount and type of pre-treatment necessary to make an RO an economical process. (Zibrida *et al*., 2000)

2.4 Membrane applications

Membrane is a physical barrier that allows certain compounds to pass through and can be classified according different pore size or molecular weight cut-off into four different types that is reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF).

Reverse osmosis is a separation technique which operates at about normal ambient temperatures, or slightly above or below and can be used for concentration and purification of liquids without a phase change. It separates salts and small molecules at relatively high pressures and has advantage over traditional evaporation techniques of removing water content, that it does not cause loss of juice flavour and colour dedgradation due to effect of high temperature. In this study, reverse osmosis was used for sorbitol purification.

Ultrafiltration can separate extremely small particles and dissolved molecules from fluids. It cannot separates molecules of similar size but only molecules which differ by at least one order of magnitude in size. The molecular, chemical or electrostatic of sample can affect the permeability of the filter medium. Particulates matter ranging in size from 1000 to 1000000 molecular weight are retained by certain ultrafiltration membranes, while water will pass through. UF membrane can be used for both purify materials passing through the filter and also to collect materials retained by the filter. (Munir, 2006).

Microfiltration membrane can remove particles or biological entities ranging between 0.025 µm to 10 µm from fluids by passage through a microporous medium such as membrane filter.(Munir, 2006)Reverse Osmosis is even more attractive in land-constrained areas because it of reduced land requirement. It is anticipated that reverse osmosis processes will be used more widely in water industry to replace the large conventional water treatment systems. Reverse osmosis was first developed in the 1950's by the US government to provide fresh drinking water for the Navy, and since then, advances have made it much more feasible for obtaining purified water from wastewater. (Tansel *et al*., 2000)

The uses of membrane for separations are becoming increasingly important in the process industries, where the membrane acts as a semipermeable barrier and separation occurs by the membrane controlling the rate of movement of various molecules between two liquid phases, two gas phase or a liquid and a gas phase. The two fluid phases are usually miscible and the membrane barrier prevents actual, ordinary hydrodynamic flow.(Geankoplis., 2003)

The membrane filtration techniques becoming a mainstream technology since early 1990's. With a number of advantages such as huge efficiency, simple equipment, convenient operation and low energy consumption, the technology has become one of the most important industrial separation techniques and has been applied extensively to various fields such as food industry and pharmaceutical. (Jing Howard, 2010). Hinkova, (2000) reported that progressively increasing transmembrane pressure and cross-flow velocity resulted in 13-26% improvement of permeate flux.

Din *et al*., (2012) states that membrane technology is considered as one of the most effective process for water and wastewater treatment. It is a compact system, economically feasible and has high pollutant removal efficiency. In the past, pressure-driven membrane processes such as RO had gained special attention due to its effective removal of pollutants, especially those with low concentrations. The use of RO is limited due to high operational cost especially when high pressure is applied. Therefore, low pressure reverse osmosis membrane (LPROM) has been introduced to water and wastewater industries in the past few years. (Din *et al*., 2012)

Most of LPROM are multi-layer thin film composed of complex polymers. The active membrane surface layer normally consists of negatively charged sulphone or carboxyl group. This helps the membranes in improving of fouling resistance against hydrophobic colloids, proteins, oils and other organics. In order to increase water flux, a charged hydrophilic layer is attached to a hydrophobic UF support membrane. This makes the membrane favorable for the orientation of water dipoles. Flux is inversely proportional to the membrane thickness. Generally, LPROM contains corrugated skin surface that can improve flux significantly. It produces specific flux more than 60 L/m2.h MPa (flux per membrane area and per net driving pressure) at low operating pressure. This flux rate is about double the flux of the previous generations of composite RO membrane. (Din *et al*, 2012)

Some advantages the production of food by using membrane processes, which it has better technological and nutritional functionalities, efficient use of material and resource, and give reduced negative impact to the environment. The main benefits of membrane is improved the production process by consistence high quality of permeate/retentate, reduced operating costs, low maintenance and pressure drop, chemical and temperature resistance and long membrane operating life and the recovery of valuable products that previously would have been lost to waste. (Scott, K. 1998) Reverse Osmosis have some advantages, over evaporation when concentrating sugar solution that can prevent the camelization and save energy. (Yurong *et al*., 1987).

However, the use of membranes cannot be applied widely due to membrane fouling. The fouling was dependent on the pore size and cause by the large particles (250nm) or coagulants. It is influenced the rejection of particles in MF and NOM in UF and NF. It is also stated that the low molecular weight acids that passed through the NF membranes and the rejection are dependent on the deposit of membrane. The mechanism of fouling can be such as pore plugging, cake formation (internal pore adsorption that reduces the internal pore diameter and charge of the deposit. In order to achieve unfouled membrane, the extent of rejection is influenced largely by the pore size or molecular weight cut-off (MWCO).The charge interactions, bridging, and hydrophobic interactions may play important role in fouling effect. For membrane separation process of reverse osmosis the size of particle are about 0.001μm and the molecular weight are in the range about 100 to 1000 Dalton. (Schafer *et al*., 2000)

In order to reduce the membrane fouling, the optimum condition of TMP and CFV should be applied as shown in Table 2.2. Defrance and Jaffrin,(1998) reported that increase in TMP will increase the membrane flux and Matsuura,(1971) shown that the concentration of sugar increase after the membrane purification process by reverse osmosis membrane. Due to fouling will increase in operational cost and lower the process efficiency. (Vrouwenvelder *et al*., 2002)

Reverse osmosis (RO) is the most economical method of removing 95% to 99% of all contaminants. The pore structure of RO membranes is much tighter than UF membranes. RO membranes are capable of rejecting practically all particles, bacteria and organics >300 daltons molecular weight (including pyrogens). Natural osmosis occurs when solutions with two different concentrations are separated by a semi-permeable membrane. Osmotic pressure drives water through the membrane; the water dilutes the more concentrated solution; and the end result is equilibrium.

Because reverse osmosis membranes are very restrictive, they yield very slow flow rates. Storage tanks are required to produce an adequate volume in a reasonable amount of time. Reverse osmosis also involves an ionic exclusion process. Only solvent is allowed to pass through the semi-permeable reverse osmosis membrane, while virtually all ions and dissolved molecules are retained (including salts and sugars). The semi-permeable membrane rejects salts (ions) by a charge phenomenon action: the greater the charge, the greater the rejection. Therefore, the membrane rejects nearly all (>99%) strongly ionized polyvalent ions but only 95% of the weakly ionized monovalent ions like sodium.

Membrane separation processes find their application in almost all branches of food and biotechnological industry. Apart from the biotechnology, the most wide-spread applications are in dairy and beverage industries, e.g. for whey protein concentration and purification (Sschkoda and Kessler, 1997), whey desalination and demineralisation, milk standardisation by ultrafiltration, etc. In the beverage industry, membranes are applied for beer and wine stabilisation to prevent the microbial decomposition, for the yeast and colloid removal, or for non-alcoholic beer production by pervaporation

(Karlsson & Tragardh,1996). Membranes are also very useful in fruit and vegetable juices production for juice purification by ultrafiltration or concentration by reverse osmosis or nanofiltration (Koseoglu *et al*. 1991).

Reverse osmosis is the most economical and efficient methods for purifying tap water if the system is properly designed for the feed water conditions and the intended use of the product water. Reverse osmosis is also the optimum pretreatment for reagent-grade water polishing systems. Reverse Osmosis is the reverse process of spontaneous osmosis. The osmosis process can be reverted by adding external pressure on the salty side so that some of the fresh water molecules on the salty side will end up on the fresh water side. The problem is that the osmotic pressure tends to force water to the more saline side, which is opposite of the desired outcome. To overcome this tendency, the osmotic pressure can be overcome by the applied pressure, forcing water from the saline side to the less saline side. Reverse osmosis is schematically presented in Figure 2.2.

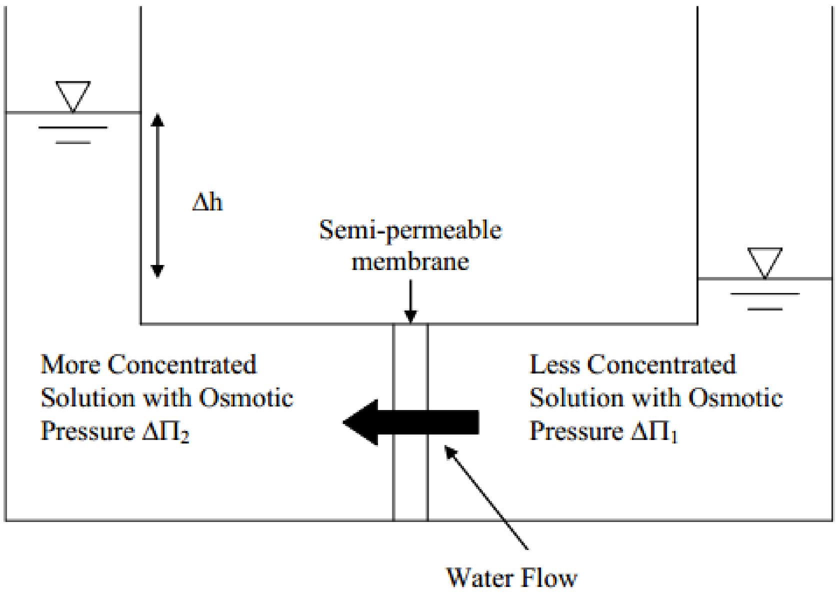

Figure 2-2: Simple osmosis